Ultraviolet radiation on the surface of Mars and a UV spectrometer on Mars.

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Introduction:

Ultraviolet (UV) radiation extends between visible violet light (400 nm) and X-rays (4 nm). The UV flux on the surface of Mars is significant in the near (300-400 nm) and far (200-300 nm) UV, while shorter wavelengths are efficiently attenuated by atmospheric absorption and scattering. Nonetheless, the UV spectrum is significant for a number of reasons. First, the subsolar surface flux in 200-400 nm range can exceed 40 W m^{-2} near perihelion, which is a significant proportion of solar flux and therefore needs to be considered in heat budgets. Second, UV is also important for the photochemistry of the lower atmosphere. Third, UV affects the chemistry of the surface minerals. Yet the 200-400 nm part of the spectrum remains unobserved from the surface. In fact, sufficiently high-resolution observations of this part of the spectrum from the surface could tell us about the mineral composition of dust, possible column abundance information of trace gases, and further our knowledge of the optical properties of Martian dust.

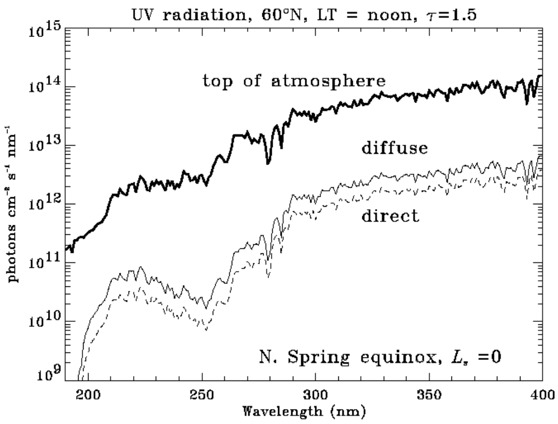
Model.

Earlier models of the UV flux on Mars (Kuhn and Atreya, 1979) had no atmospheric dust and also used gas absorption data measured at room temperature that overestimate absorption for lower Martian temperatures. For fixed wavelengths above 190 nm, the absorption cross-section of CO_2 can decrease by a factor of ~2 to 6 if the temperature is lowered from 300 to 200 K. We have developed a relatively simple radiative transfer model for the transmission of UV to the surface of Mars. The model is briefly described in Cockell et al. (2000) and more extensively in Patel et al. (2002). Our updated model for UV incorporates dust and more recent data for the solar spectrum, gas absorption, and UV surface albedo (Patel et al., 2002). Dust optical properties were taken from Ockert-Bell (1997). A result of the model is shown in Fig. 1 where a high column abundance of O_3 is used. The dusty atmosphere gives rise to a dominance of diffuse over direct flux above a visible optical depth ~1.4.

The Problem of Dust Optical Properties:

The optical properties of Martian dust in the UV region are the largest source of uncertainty in calculating surface fluxes of UV. Dust absorbs and scatters UV significantly. Studies in the UV part of the spectrum have generated a range of dust optical properties unlike the properties in the visible where there is reasonable agreement. Pang et al. (1976) analyzed Mariner 9 UV spectrometer data to derive complex indices of refraction at 268 nm and 305 nm using Mie theory, while Chylek and Grams (1978) repeated the analysis using non-spherical particle theory. These studies found the dust at these wavelengths to be less absorbing than the results of Ockert-Bell et al. (1997). The opposite result is seen in Hubble Space Telescope (HST) data from Wolff et al. (1997) who used Wide Field Planetary Camera observations of dust storms in the Hellas and polar regions, giving a more absorbing dust in the UV. Zurek (1978) used complex indices of refraction from the data of Pang and Ajello (1977) to derive the optical properties in the UV using Mie theory. These results show both some agreement and disagreement across the UV spectrum with Wolff et al. (1997) and Ockert-Bell et al. (1997). Thus, clearly more measurements are needed in the UV to resolve such widespread discrepancy.

Fig. 1 UV flux in a high-latitude case.



A UV Spectrometer for the surface of Mars:

In order to determine the diffuse and direct components of irradiance, and help better understand the optical properties of dust, it is obvious that a UV spectrometer is needed on the surface of Mars. The Beagle 2 Lander has 5 sensors centered around 5 wavelengths distributed across 200-400 nm and one broadband sensor covering the entire 200-400 nm range (Patel et al., 2002). Beagle 2 will offer the first direct measurement of UV, but will clearly offer only very coarse resolution. A spectrometer with high spectral resolution could resolve features such as weak absorption bands at 210, 230 and 250 nm of Martian dust, which arise from TiO_2. TiO_2 has been identified in small amounts (~1%) in the Mars Pathfinder soil (Bell et al., 2000).

The simplest way to detect ozone on Mars is also through measurement using optical spectroscopy in the Hartley continuum:

$$O_3 + h\nu\ (\lambda < 300\ \text{nm}) \rightarrow O_2 + O(^1D)$$

With sufficient resolution and signal-to-noise, a Mars UV surface spectrometer could, in principle, measure O_3 column abundance. Even though O_3 is present at much smaller levels than on Earth, the O_3 absorption cross-section is still very large with a maximum of ~10^{-17} cm^2 at 255 nm at 218 K.

Currently, we are investigating adapting a commercial instrument (a USB 2000 Ocean Optics grating spectrometer) for use on Mars. The bandwidth is from 200 nm to 560 nm, and therefore overlaps in the visible where comparisons can be made. The spectrometer has a 600lines/mm grating and uses a crossed Czerny-Turner optical system and CCD detector array. The current signal/noise (S/N) ratio is 250/1; a higher S/N is should be achievable and would lend feasibility to detecting Martian ozone. Fig 2 shows some preliminary laboratory calibration of the instrument against a deuterium lamp. A spectral resolution of ~1 nm is also achievable. Small size and volume are also key goals (Fig. 3).

Fig 2: Lab spectral calibration (counts vs. wavelength (nm) of our spectrometer using a deuterium lamp signal. Prominent deuterium spectral lines allow wavelength calibration.

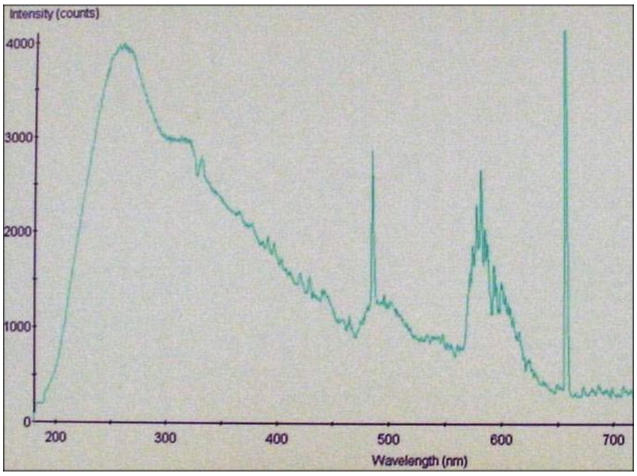


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Fig 3: Our UV spectrometer for the Martian surface can be made sufficiently small to be a feasible instrument for future NASA landers.